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COMPARISON OF FIELD- AND LABORATORY-DEVELOPED ESTUARINE BENTHIC COMMUNITIES FOR TOXICANT-EXPOSURE STUDIES

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Abstract. The structures of macrobenthic communities that colonized sand-filled boxes in laboratory and field were compared to learn if laboratory-developed assemblages of animals used in toxicity studies realistically simulate those in nature. Laboratory boxes were colonized for eight weeks in the Spring and Fall by planktonic larvae from continuously-supplied unfiltered seawater; field boxes, by naturally-occurring estuarine animals. Laboratory communities had larger numbers, but fewer species than field communities. One-fourth of the species found in field boxes also occured in laboratory boxes. Species density, diversity, and dominance were similar in both environments in the Fall, but differed in the Spring. The degree of similarity of laboratory assemblages of benthic animals to the highly variable assemblages in the field indicates applicability of laboratory toxicity studies to nature.

1. Introduction

Increasing emphasis is being placed on use of benthic macrofauna to evaluate effects of toxicants on marine environments because changes in species composition, density, and structure are considered good indicators of the effects of pollution and stress (Swartz, 1978). The benthos is particularly susceptible to pollution because its animals are sedentary and because of the affinity of many pollutants for sediments. In addition, benthic-community tests allow comparison of interspecific interactions, and the testing of a variety of species from representative phyla generally not tested in typical single-species bioassays.

Estuarine benthic communities colonized in the laboratory have been used to test a variety of toxic compounds. Communities were exposed via water or sediment to a phthalate, a polychlorinated biphenyl, a chlorine-produced oxidant, five insecticides, three oil drilling fluids, and four components of drilling fluids (Hansen and Tagatz, 1980; Rubenstein *et al.*, 1980a, b,; Sheridan and Badger, 1981; Tagatz *et al.*, 1979a, b, 1982b).

Experimantal design differed among studies but generally consisted of 8 or 10 sand-filled aquaria (9 × 56 × 9 cm deep, 6 cm sand) for a control and for each of three toxicant concentrations (Hansen and Tagatz, 1980). The aquaria were supplied continuously with unfiltered natural seawater (200 ml min^{-1}) for 8 or more weeks. Introduction of the toxicant was concurrent with the beginning of colonization by planktonic larvae. After colonization, numbers of individuals and species of living animals in contaminated and control aquaria were compared.

Recently, studies have been conducted to determine the effects of toxicants on field-developed benthic communities for comparison with studies on laboratory-

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developed communities using the same toxicants (Tagatz *et al.*, 1981, 1982a; Tagatz and Ivey, 1981). Boxes, 32 × 32 × 6 cm deep, were filled with sand and placed in 3 m of water in Santa Rosa Sound. After 8 weeks, boxes with their established communities were transferred to the laboratory. Four or more boxes served for the control and for each of three 1-week exposures to a toxicant. Community structures of field- and laboratory-developed benthic communities were compared for each compound. However, precise comparisons could not be made because of limited replication or because the period of colonization and aquarium size differed.

To better compare laboratory- and field-colonized benthic communities, laboratory and field studies reported here were conducted concurrently using eight replicates of the same type of test container during two seasons. For simulation of realistic occurrences in laboratory studies, variability should not drastically differ from that in the field.

2. Materials and Methods

2.1. Experimental communities

Structures of macrobenthic animal communities that settled in sand-filled boxes in the laboratory and in Santa Rosa Sound were compared during each of two seasons. Laboratory boxes were colonized by settling planktonic larvae in unfiltered seawater continuously supplied from Santa Rosa Sound. Field boxes, located at a water depth similar to our seawater intake, and approximately 100 m away, were colonized by naturally-occuring animals. Fall studies were conducted from September 3 to October 27, 1980 (7 weeks, 5 days); Spring studies, from March 9 to May 4, 1981 (8 weeks). The salinity of water entering our laboratory during colonizating averaged 25.5 ppt (22 to 29 ppt) in the Fall and 27.5 ppt (18.0 to 32.5 ppt) in the Spring; temperature, 26 °C (19 to 30 °C) in the Fall and 20.5 °C (15.5 tot 26 °C) in the Spring. Periodic measurements indicated that salinity and temperature regimes were similar in the area where our field boxes were located.

Boxes, 32 × 32 × 6 cm deep, were constructed of acrylic plastic and filled with clean silica sand (particle size, 0.2 to 0.8 mm) dredged at least a year previously from Santa Rosa Sound. In the laboratory, a group of four boxes was placed in each of two acrylic-plastic box-frames that, when filled, contained a 3-cm layer of water over the sand. Unfiltered seawater was delivered continuously at 2 l min^{-1} to the center of each frame; water flowed from the frame through notched openings on all sides. Illumination consisted of alternating 12-h periods of light and darkness. Concurrent to the laboratory study, eight boxes (in two groups of four) were placed by SCUBA divers in 3 m of water, at the approximate depth and about 100 m from the pump-intake that supplied unfiltered seawater to the laboratory boxes. The boxes, positioned in the substratum so that their surfaces were level with the surrounding sand, were covered with 1/4-inch (6.4 mm) hardware cloth to prevent major predation by such large predators as fishes and crabs. Although varying degrees of predation are a natural part of the benthos, large predators are not present in our laboratory benthic studies where predation could mask the effects

of a toxicant. We chose also to have atypical predation in our field boxes to allow for better comparison of animals that newly colonize field and laboratory communities.

After 8 weeks of colonization, field boxes were collected by divers and covered with acrylic plastic for immediate transfer to the laboratory. In the laboratory, each group of four field boxes was placed in a box-frame receiving seawater as described above. Temperature and salinity in field and laboratory at transfer were the same.

Communities were harvested by passing the contents of each box through a 1-mm mesh sieve; animals retained were preserved and identified.

2.2. Statistical analyses

Various biological indices of community structure were applied to our laboratory- and field- derived data. The Shannon-Weaver (1963) index (H', $\log_{10}$ was calculated to assess differences in species diversity, an integrated measure of richness and evenness. Simpson's (1949) index was used as a comparative measure of dominance; degree of dominance by the more abundant species determines the evenness of distribution of individuals among species. The Bray-Curtis percentage dissimilarity index, 1-W, was used to document spatial-temporal faunal heterogeneity between field and laboratory communities (Swartz *et al.*, 1976); where W = sum of lesser ni/N for each species found in both samples (ni = number of individuals of the i^{th} species, N = total number of individuals in a sample). Index values range from 1.0 when the collections have no species in common to 0 when all species are common and the distribution of individuals is the same on a percentage basis. We also determined the variance of total number of individuals for the eight replicates between laboratory and field. Estimated variances were determined for laboratory and field and compared using the test statistic, F, which was calculated as the ratio of the larger estimate of variance to the smaller ($F = S_1^2/S_2^2$).

3. Results

During the Fall, 415 animals (40 species of 7 phyla) were collected from field-colonized communities and 1295 animals (39 species of 5 phyla) from laboratory-colonized communities (Table I); during the Spring, 488 animals (42 species of 7 phyla) occurred in the field and 855 animals (22 species of 6 phyla) in the laboratory (Table II). Thus, laboratory communities had more animals of fewer species than field communities (Table III). However, both consisted primarily of the same four phyla: Annelida, Arthropoda, Chordata, and Mollusca. In addition, all communities were dominated by only a few species of animals. Except for field communities in Spring where four species made up about one-half of the total individuals (Simpson's index of dominance, 0.91), one species accounted for one-half of the animals collected in each situation (dominance, 0.67 to 0.75).

Covers over the field boxes did not prevent heavy predation of clams by oyster drills and moon snails. Over one-half of the pelecypods were dead, most with bore-holes produced by these gastropods. Although the covers may have attracted these predators, we observed a similar degree of predation in benthic samples from adjacent natural areas.

TABLE I

Animals in field- and laboratory- colonized benthic communities, September 3 to October 27. Replicates were pooled

Taxon	Field	Laboratory
Annelida		
Capitella capitata	229	5
Unidentified polycheate A	4	
Cistenides gouldii	3	5
Podarke, near *guanica*	3	
Loimia viridis	2	
Notomastus hemipodus	2	
Spiophanes bombyx	2	
Ancistrosyllis bassi	1	
Armandia agilis	1	118
Axiothella mucosa	1	
Dasybranchus lunulatus	1	
Dispio uncinata	1	
Glycera dibranchiata	1	
Gyptis vittata	1	
Haploscoloplos robustus	1	
Nereiphylla fragilis	1	
Nerine agilis	1	
Travisia carnea	1	
Eteone trilineate		12
Unidentified polychaete B		11
Nereis pelagica occidentalis		7
Sabella microphthalma		5
Prionospio heterobranchia texana		4
Mediomastus calidorniensis		3
Capitomastus aciculatus		2
Hydroides protulicola		2
Maldanidae		2
Capitillides jonesi		1
Owenia fusiformis		1
Polydora ligni		1
Polydora socialis		1
Pomatoceros caerulescens		1
Trypanosyllis vittigera		1
Total Annelids	256	182
Chordata		
Branchiostoma caribaeum	64	
Mollusca		
Diastoma varium	10	112
Laevicardium mortoni	8	603
Mitrella lunata	6	30
Anomalocardia auberiana	5	
Crassostrea virginica	2	
Morula didyma	2	
Persicula sp.	2	
Triphora nigrocincta	2	
Acteorina canaliculata	1	151

Table I (Continued)

Taxon	Field	Laboratory
Crepidula maculosa	1	
Mangelia stellata	1	
Tellina alternata	1	12
Musculus lateralis		36
Amygdalum papyrium		16
Lyonsia hyalina floridana		12
Mulinea lateralis		9
Anadara transversa		6
Cyrtopleura castata		1
Geukensia demissa		1
Tagelus divisus		1
Trachycardium muricatum		1
Unidentified pelecypod		1
Total Mollusks	41	992
Rhynchocoela		
Cerebratulus lacteus	26	
Arthropoda		
Corophium acherusicum	15	97
Acanthohaustoria millsi	3	
Ampelisca vadorum	2	
Ampelisca verilli	2	
Pinnixa cylindrica	2	
Processa sp.	1	
Balanus amphitrite nivens		2
Total Arthropods	25	99
Echinodermata		
Ohiophragmus filograneus	2	
Synaptula hydriformis		11
Amphioplus abditus		2
Pentamera sp.		1
Total Echinoderms	2	14
Coelenterata		
Actinaria	1	8
Total all phyla		
Individuals	415	1295
Species	40	39

Mollusk density was greatest in the laboratory, probably because of minimal gastropod predation.

Ten species occurred in both field and laboratory communities during each season (Table III). The species accounted for 14.5% of a total of 62 species in Fall communities (three-quarters of the total animals) and 18.5% of a total of 54 species in Spring communities (one-quarter of the total animals).

TABLE II

Animals in field- and laboratory- colonized benthic communities, March 9 to May 4. Replicates were pooled

Taxon	Field	Laboratory
Annelida		
Cistenides gouldii	88	31
Haploscoloplos sp.	79	
Capitella capitata	47	
Prionospio heterobranchia texana	15	1
Glycera americana	9	
Spiophanes bombyx	7	
Sabellidae	4	3
Cirratulidae	3	
Loimia viridis	3	
Lumbrinereis sp.	3	
Neanthes succinea	3	8
Gyptis vittata	1	
Paraprionospio pinnata	1	
Phyllodoce sp.	1	1
Sthenelais articulata	1	
Terebellidae or Ampharetidae	1	
Armandia agilis		11
Polydora sp.		1
Sabellaria vulgaris		1
Total Annelids	266	57
Mollusca		
Laevicardium mortoni	45	
Diastoma varium	17	
Mitrella lunata	9	
Tellina sp.	6	
Marginella apicina	3	
Anadara transversa	2	
Crepidula maculosa	2	
Crepidula plana	2	1
Lyonsia hyalina floridana	2	33
Anomalocardia auberiana	1	
Ensis minor	1	128
Mangelia quadrata	1	
Musculus lateralis	1	1
Nassarius vibex	1	
Neritina virginea	1	
Mulinia lateralis		144
Polinices duplicatus		12
Dinocardium robustum		1
Triphora nigrocincta		1
Total Mollusks	94	321
Arthropoda		
Acanthohaustorius millsi	31	
Ampelisca abdita	14	
Grandidierella bonnieroides	13	
Tanaidacea (Apseudidae)	3	

Table II (Continued)

Taxon	Field	Laboratory
Neopanope texana	2	
Upogebia affinis	2	
Pagurus annulipes	1	
Corophium acherusicum		16
Bowmaniella sp.		10
Oxyurostylis smithi		2
Total Arthropods	66	28
Chordata		
Branchiostoma caribaeum	46	
Molgula manhattensis		447
Echinodermata		
Leptosynapta inhaerens	12	
Rhynchocoela	3	
Hemichordata		1
Phoronida		
Phoronis architecta	1	1
Total all phyla		
Individuals	488	855
Species	42	22

Species density, diversity, and dominance for the field and laboratory were similar in the Fall, but differed in the Spring (Table III). In the Spring, numbers of species were 42 in the field and 22 in the laboratory; species diversity, 1.21 in the field and 0.68 in the laboratory; and Simpson's Index, 0.91 in the field and 0.67 in the laboratory. Relative

TABLE III

Comparison of population structure of field- and laboratory- colonized communities during Fall and Spring

	Fall		Spring	
	Field	Laboratory	Field	Laboratory
No. of phyla	7	5	7	6
No. of species	40	39	42	22
No. of species in common	10	10	10	10
% of species in common	25.0	25.6	23.8	45.4
No. of individuals	415	1295	488	855
No. of individuals for sp. in common	275	1141	118	208
% of individuals for sp. in common	66.3	88.1	24.2	24.3
Species diversity (H')	0.81	0.87	1.21	0.68
1-Simpson's Index of Dominance	0.67	0.75	0.91	0.67
Replicate varability (individuals)	3316	3462	340	1750
Dissimilarity Index between field and laboratory	0.89	—	0.94	—

abundance of individual species differed greatly between laboratory and field boxes during both seasons. These differences are reflected by high Bray-Curtis Dissimilarity Indexes for the Fall, 0.89, and for the Spring, 0.94. The variability in number of animals among replicates was significantly different (5% level) between field and laboratory communities in the Spring, but not in the Fall. F values and the 95% confidence intervals for the ratio of population variance are 5.14 (1.03, 25.65) for the Spring and 1.04 (0.21, 5.19) for the Fall.

Although the percentage composition of individuals by phylum differed in field and laboratory communities, that of species was very similar (Table IV). By number of individuals, annelids dominated field benthos and mollusks or chordates dominated laboratory benthos. In numbers of species, annelids and mollusks dominated and were about equally represented in both field and laboratory boxes.

TABLE IV

Percentage composition of individuals and species (by phylum) collected from field- and laboratory-colonized communities during Fall and Spring

	Individuals				Species			
	Fall		Spring		Fall		Spring	
Phylum	Field	Lab.	Field	Lab.	Field	Lab.	Field	Lab.
Annelida	61.7	14.1	54.5	6.7	45.0	46.2	38.1	36.4
Arthropoda	6.0	7.6	13.5	3.3	15.0	5.1	16.7	13.6
Chordata	15.4	0	9.4	52.3	2.5	0	2.4	4.5
Mollusca	9.9	76.6	19.3	37.5	30.0	38.5	35.7	36.4
Other phyla	7.0	1.7	3.3	0.2	7.5	10.2	7.1	9.1

4. Discussion

Laboratory-colonized communities shared many attributes with field-colonized communities. Both consisted primarily of Annelida, Arthropoda, Chordata, and Mollusca. Annelids and mollusks were represented by the most species and by about the same number in field and laboratory. In addition, only a few species represented over one-half of the animals in each community. In some instances, within phyla, the more abundant species were the same for the field and laboratory. About one-quarter of the species found in field boxes also colonized the laboratory boxes. Of 30 species found only in field boxes during the Fall study, 15 occurred in other laboratory benthic studies at Gulf Breeze (cited in the Introduction); of 32 species found during the Spring study, 22 occurred in these other studies. In comparison to our studies, Flint *et al.* (1982) found a higher percentage (42%) of species occurring in both laboratory and field colonized sediment boxes in Aransas Bay during the Winter. Of an overall total of 82 species, 34 were common to both environments.

Benthic communities in field boxes were considered to be representative of animals concurrently colonizing surrounding natural areas, but not necessarily of similar community structure. Flint *et al.* (1982) compared structure and biomass of macrobenthos from natural estuarine bottom at Aransas Bay, Texas with colonization in benthic test systems placed in the laboratory and in the Bay. Cluster analysis of the species from each situation indicated that laboratory-colonized samples were most different from the other groups and that distribution of species in field test systems and the natural bottom was similar. However, we believed that the microecosystems in our field boxes, level with the surrounding sand, would be a better field representation for comparison with animals that simultaneously colonized in the laboratory than would be samples from the wide variety of long-established natural communities. In addition, it is difficult to obtain grab samples of comparable size of the natural bottom without disturbing the integrity of existing animal communities.

Taxa which occur in both laboratory and field communities vary seasonally, between years, with duration of colonization, and with field site. Species composition varied greatly between our Fall and Spring studies. In the field, only 15 of 67 species (22.4%) were common to both seasons; in the laboratory, only 9 of 52 species (17.3%). Dominant species may also vary for the same season in different years. In 12 successive laboratory benthic studies in South Carolina over 2 yr, seasonal dominants differed between years (Sheridan and Badger, 1981). Time available for colonization is also a consideration since structural differences due to settling of animals out of phase by area would be minimized over time. Finally, species composition varies with location in the field. In earlier studies conducted at Gulf Breeze in the Spring with field benthic boxes located at another site, 30% of the taxa were common to field and laboratory, compared to 18.5% in the present Spring study (Tagatz *et al.*, 1981).

In evaluating field- and laboratory-derived benthic communities for use in toxicity studies, each has advantages and disadvantages. Both result in sufficient numbers of benthic macrofauna to allow determination of toxicant effects on a variety of taxa. Simultaneous studies using field- and laboratory-colonized communities can provide corroborating data on toxicant effects as well as data peculiar to each study. For example, abundance of amphipods was significantly altered by fenvalerate in both laboratory and field situations; however, lancelets, very sensitive to the chemical in field-colonized communities, did not occur in laboratory-colonized communities (Tagatz and Ivey, 1981).

The laboratory-colonized benthic community test appears to be a more sensitive measure of toxicity than the field-colonized test. Introduction of the toxicant to laboratory boxes is concurrent with the beginning of colonization by generally more sensitive early larval forms, whereas later developmental stages are exposed in field boxes and for a shorter period of time. Since benthos in field boxes cannot readily be exposed artificially to a toxicant *in situ*, they must be brought into the laboratory for exposure. We learned that significant mortality occurred among arthropods and mollusks at concentrations of chlorpyrifos or pentachlorophenol an order of magnitude lower during simultaneous colonization and exposure, in comparison to exposures after communities

had developed in the field (Tagatz *et al.*, 1981, 1982a). In addition, exposure during early community development provides for the determination of sublethal parameters, such as bioaccumulation of the chemical and effects on growth or behavior. For example, growth of clams exposed to Sevin and tunicates exposed to oil-drilling fluid significantly decreased in laboratory benthic communities at sublethal concentrations of these compounds (Tagatz *et al.*, 1979, 1982b).

The primary reason for using field- instead of laboratory-colonized boxes in toxicity studies is that, theoretically, they are structurally more equivalent to natural macrofaunal communities. Also, by exposing an established community to a toxicant, deaths can often be enumerated to document toxicant effect; in laboratory exposures of early larval forms, deaths are inferred by absence of individuals. However, care must be taken to determine if mortality among mollusks is field-related (due to predation by gastropods) or toxicant-related. Field boxes containing established benthic communities or clean sediment can also be used in natural areas to detect contaminants and to monitor their effects.

We conclude from our studies that the structure of laboratory-colonized communities is similar to those simultaneously colonized in the field. Admittedly, many differences exist. However, these differences seem minimal when considering the large variability of natural benthic communities within an area. Because newly settled animals interact as additions to a wide variety of already established natural communities, it would also be difficult to select a typical natural community for testing. Giddings (1981) discussed how a model ecosystem may be a reasonable substitute for a field experiment when it is typical of, but not necessarily identical to, any particular example of its ecosystem type. He also states that the 'validity' of a model ecosystem experiment can be assessed by comparing its behavior with the behavioral range of natural ecosystems, and that results are best viewed as examples of what could occur in a typical ecosystem. Until a good method is devised to artificially expose field-colonized communities *in situ*, it appears that the operationally simpler laboratory benthic test is a reasonable alternative in toxicity studies. It has proven to be a sensitive measure of pollution for a variety of animals in a community situation. However, comparative field and laboratory studies are important to delineate limitations of laboratory results and to indicate methods for better field applicability.

5. Summary

Comparison of field- and laboratory-developed experimental benthic communities indicated their applicability to nature and for toxicant exposure studies. Laboratory communities had more animals of fewer species than the field communities. Both consisted of the same dominant phyla, many of the same species, and were similar in the relative abundance of species. Similarities and differences of other structural attributes varied with season. Although experimental field-colonized communities may be more equivalent to natural assemblages of animals, the laboratory-colonized communities appear to provide a more sensitive measure of toxicity. Both, however, result in sufficient numbers of benthic macrofauna to allow determination of toxicant effects on a variety of taxa.

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